

Exploring the conditions leading to an exceptional early bloom of *Dinophysis acuminata* in northwest Spain during 2012

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Abstract

In a conceptual model proposed before, the onset of the upwelling season and availability of *Mesodinium rubrum* prey are essential conditions for the initiation of *Dinophysis acuminata* blooms in the Galician Rías Baixas (NW Spain). Distribution of sexual cysts from the previous year in the top sediment layer is an important parameter in forecasting models of cyst-forming species (e.g. *Alexandrium* spp.). But the existence of sexual cysts of *Dinophysis* spp. has not been confirmed, *Dinophysis* planozygotes can divide and produce vegetative cells directly, and it is possible that species of this genus do not rely on sexual cysts but on some kind of overwintering planktonic form as a seeding mechanism. Here we examine winter conditions—persistence or absence of overwintering cells of *Dinophysis* within the rías and the adjacent shelf and time of initiation of the upwelling season—from observations in the last 20 years. Our ultimate goal was to explain the abundance and early initiation in April 2012 of an extraordinary bloom of *D. acuminata*, in what appeared to be a mesoscale event affecting other regions in Western Europe. The dynamics of *D. acuminata* populations appeared tightly coupled to the upwelling season. Our results suggest that anomalous upwelling patterns (predominance of upwelling in winter) combined with the presence of overwintering (inoculum) cells lead to early initiation of the *Dinophysis acuminata* growth season.

Keywords: *Dinophysis acuminata*, upwelling patterns, interannual variability, exceptional bloom, Galician Rías.

Introduction

Several species of *Dinophysis* produce lipophilic shellfish toxins (OA, DTXs, PTXs) and are the main cause of shellfish harvesting closures in Western Europe, becoming a chronic problem on the Atlantic coasts of Iberia, Brittany (France), SW Ireland, Skagerrak-Kattegat, and Norwegian Sea. *Dinophysis acuta* and in particular *D. acuminata* pose the main threat to the sustainable exploitation of blue mussels in Galicia (NW Spain), site of a production up to 300,000 t y⁻¹. *D. acuminata* populations may occur through the whole upwelling season (spring to early autumn), the first maxima (>10³ cells L⁻¹) in early June (Velo-Suarez et al. *in press*). Thanks to monitoring inputs and research projects, considerable knowledge has been gained concerning seasonality and short-term response of *Dinophysis* spp. to environmental conditions. But we still know very little about the causes of their inter-annual variability. Single-species predictive models require a sound

knowledge of the biology of the target organism. In cyst-forming dinoflagellates, sexual cysts density on the top sediment layer is a very important parameter, the potential inoculum, used in forecast models (Anderson et al., 2005). Observations of planozygote division—with no need of sexual cyst maturation—and the rare occurrence of putative cysts (sometimes misidentified *Fragilidium*—that recently fed on *Dinophysis*—asexual cysts) during exceptional blooms support the view that *Dinophysis* spp do not rely on resting cysts germination as a seeding strategy (Escalera and Reguera, 2008). Identification of the “pelagic seed bed” (*sensu* Smayda, 2002) and the way it is introduced in the Galician Rías. This paper examines the winter conditions in the last 20 years to explain the exceptional early bloom of *D. acuminata* in 2012.

Material and Methods

The Galician Rías Baixas (NW Spain) (Fig. 1) are located in the northern limit of the Canary Current upwelling system. This region is under the influence of the North Atlantic weather system, where the meteorological dynamics is highly conditioned by the seasonal evolution of two atmospheric systems, the Azores high-pressure and the Iceland low-pressure (Wooster *et al.* 1976). The displacement of atmospheric high-low pressures, favouring upwelling or downwelling events determines a seasonal upwelling regime, from April to October (McClain *et al.* 1986).

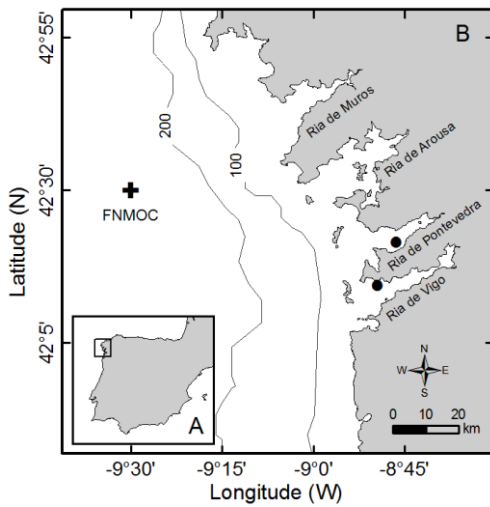


Fig. 1. Galician Rías Baixas (NW Spain), showing the location of the 2 “hot spots” (black circles) and the position for the Ekman transport estimates (black cross).

Time series of days of harvesting closures at the “hot spots” in Ría de Vigo and Ría de Pontevedra and weekly reports on phytoplankton distribution at the Ría de Pontevedra from 1993 to 2012 were obtained from the Galician Monitoring Program (INTECMAR). Monthly reports of phytoplankton distributions in a transect from Ría de Vigo to the adjacent shelf were obtained from the programme *Radiales* (IEO). The time series of six-hourly Ekman transport data over the last 46 years (1967–2011), were estimated using model data from the U.S. Navy’s Fleet Numerical Meteorology and Oceanography Centre (FNMOC) derived from Sea Level Pressure (www.indicedeafloreamiento.ieo.es) on a grid of approximately $1^\circ \times 1^\circ$ centred at 42.5°N 9.5°W , representative for the study area (Fig. 1).

Results and discussion

The days of harvesting closures per year at the hot spots in the Ría de Vigo and Ría de Pontevedra evidenced a high interannual variability, with minimum days of closure in 1996 and 1997 and maxima on 1995, 2004 and 2005 (Fig. 2).

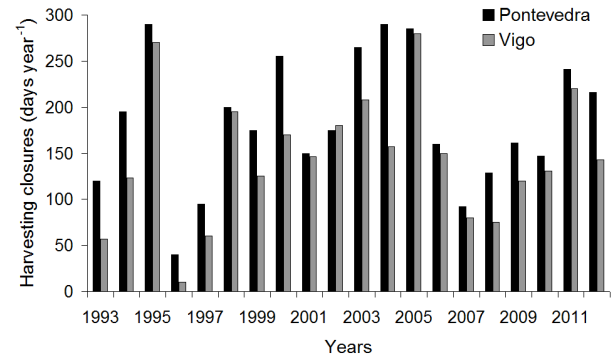


Fig. 2. Days of harvesting closures per year (lipophilic toxins) at the hot spots in Ría de Vigo and Ría de Pontevedra.

The monthly average Ekman transport ($\text{m}^3 \text{s}^{-1} \text{km}^{-1}$) showed a typical pattern described by McClain *et al.* (1986) and characterized by an upwelling-season from April to October with winter and autumn transitions in March and October (Fig. 3).

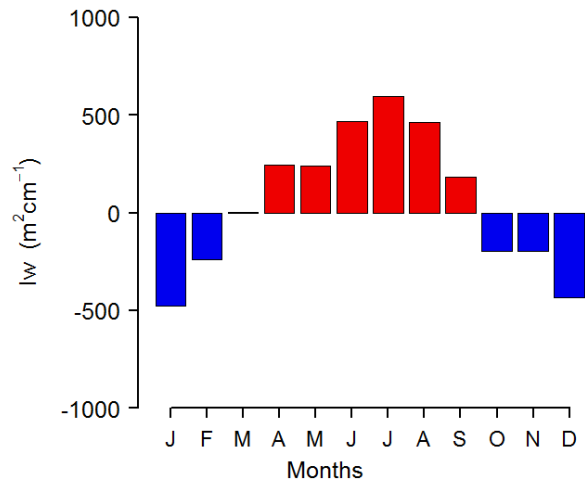


Fig. 3. Monthly averaged (1967-2011) Ekman transport ($\text{m}^3 \text{s}^{-1} \text{km}^{-1}$) estimated from the FNMOC-model.

The inter-annual variability of *D. acuminata* during the last 20 years showed maximum cell concentrations in 2010-2012, and minimal densities in 1996 and 1997 (Fig. 4).

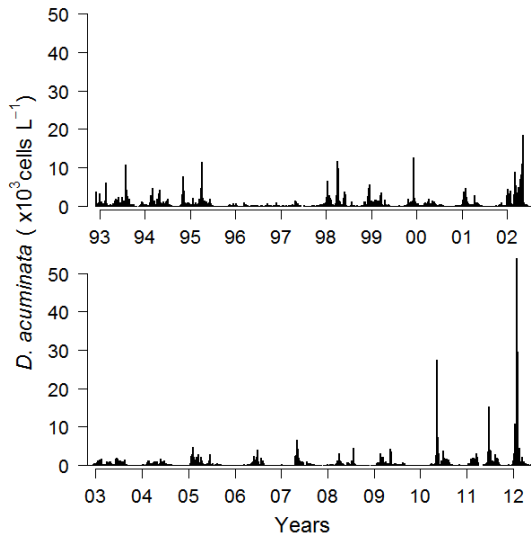


Fig. 4. Inter-annual variability of *D. acuminata* from 1993 to 2012 in the Ria de Pontevedra.

During 2012 an extraordinary bloom of *D. acuminata* was observed at the Rias Baixas in terms of abundance and early initiation. A maximum of 6×10^4 cells L^{-1} was observed in integrated hose samples (0-5m) at a shallow station in the innermost part of Ria de Pontevedra in April (Fig. 5).

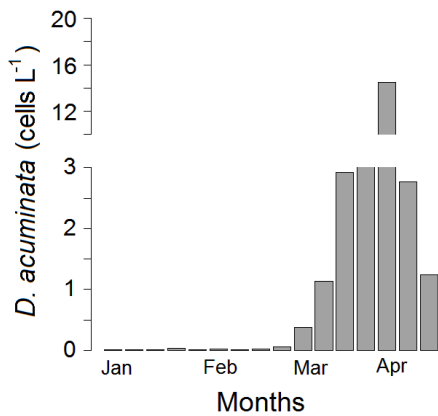


Fig. 5. Weekly average of *D. acuminata* densities ($\times 10^3$ cells L^{-1}) from 10 stations (integrated hose samples) in Ria de Pontevedra from January to April 2012.

The analysis of the time-series of *D. acuminata* distribution evidenced that years with early bloom initiation (April)—e.g. 2000, 2005 and 2012—coincided with anomalous patterns of Ekman transport characterized by upwelling-dominance during the winter months (Figs. 6, 7). In contrast,

years characterized by late initiation of *D. acuminata* blooms (July – September)—mainly 2002 and 2010—coincided with normal upwelling patterns, i.e. dominance of downwelling in the winter months (Figs. 6, 7).

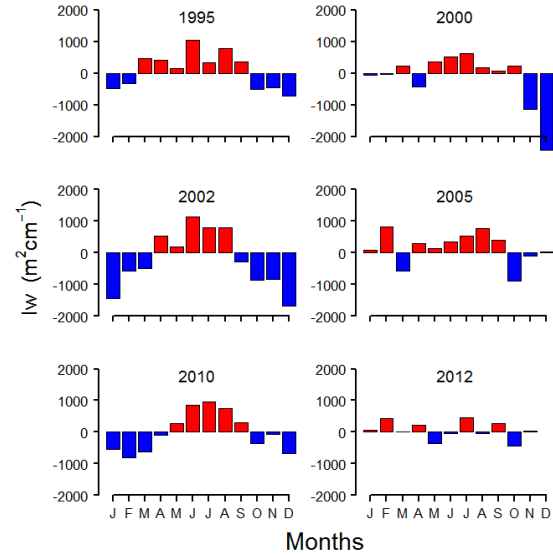


Fig. 6. Ekman transport ($m^3 s^{-1} km^{-1}$) during selected years with normal (left) and anomalous (right) upwelling patterns in relation to the historical monthly mean.

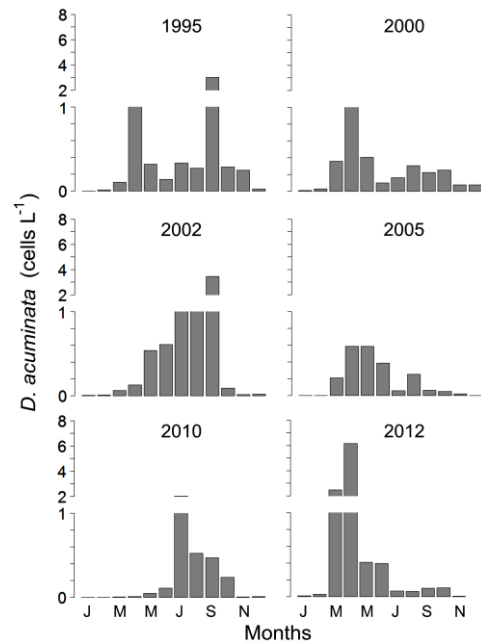


Fig. 7. Monthly mean of *D. acuminata* ($\times 10^3$ cells L^{-1}) in Ria de Pontevedra during selected years with normal (left) and anomalous (right) upwelling patterns.

The presence of scattered overwintering cells of *Dinophysis* (Jan-Feb) that would act as the inoculum population is tested here as one of the key factors explaining early initiation of the blooms. This mechanism is the essence of the “pelagic seed bank” conceptual model proposed by Smayda (2002). This model proposes a pelagic analogue of the “seed (cysts) beds” deposited onto the sea sediments, in particular for species that do not rely on sexual cyst germination as their inoculum. In this context, years of early high densities of *D. acuminata* in the Ria de Pontevedra during the last 20 years—mainly 2000 and 2012—appeared associated with the presence of overwintering cells in combination with anomalous winter upwelling patterns (Table 1). That was the case in Ria de Pontevedra in 2012, when the presence of scattered individual cells during the winter months was evident (Fig. 8).

Table 1. Maximum cells concentration of *D. acuminata* during winter months in Ria de Pontevedra from 1993 to 2012.

Year	Months											
	January				February				March			
1993												
1994												
1995												
1996												
1997												
1998												
1999												
2000												
2001												
2002												
2003												
2004												
2005												
2006												
2007												
2008												
2009												
2010												
2011												
2012												

Cells L ⁻¹	0	100	1000	10000	>10000
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Conclusions

The initiation of the growth season of *D. acuminata* appears strongly coupled to the upwelling season. Early initiation of the blooms seems also associated with the presence of overwintering cells in the outer reaches of the Rías

and their adjacent shelf. A combination of these two factors was associated to the exceptional intense bloom of *D. acuminata* in 2012.

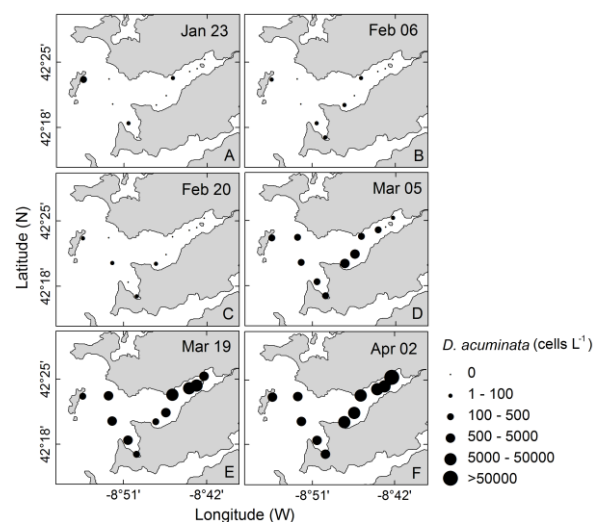


Fig. 8. Spatial and temporal distribution of *D. acuminata* at the Ría de Pontevedra from January 23 to April 02, 2012.

Acknowledgements

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